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Interferometer for Large Surfaces

James B. Saunders and Franz L. Gross[1]

An interferometer is described that permits the testing of large areas, such as layout plates. The extension to large areas is obtained by causing a collimated beam of light to reflect from the specimen at a large angle of incidence. The resultant fringe pattern is a contour map of the surface relative to an arbitrarily chosen plane and the contour interval is a function of wavelength and angle of incidence.

1. Introduction

An interferometer for testing large surfaces has been described by Linnik.[2] However, in spite of certain advantages, the Linnik interferometer has not been used extensively in this country. This lack of application may be due to the complexity of the instrument.

The instrument described here is relatively simple and easy to operate, is twice as sensitive as the Linnik interferometer, and is relatively free from vibrations.

2. Optics of the Interferometer

The optics of this interferometer are shown schematically in figure 1. The light from a source at S is collimated by the lens L_1, and separated into two coherent beams by the semireflecting dividing plane of a Kösters double image prism.[3] [4] The entrance angle of the collimated light may be adjusted to give any desired deviation θ between the component beams 1 and 2. Beam 1 is reflected normally from mirror M_1 and returns upon itself. Beam 2 is reflected from the surface to be tested at an angle of incidence of $90-\beta$ degrees, then normally from mirror M_2 and returns along its previous path to the dividing plane of the prism, where it recombines with beam 1. The observer at E sees interference fringes on the superimposed images of the two mirrors.

The gross aspects of the fringe pattern (fringe direction and spacing) are controlled by the wedge angle between the wave fronts of beams 1 and 2, while the small irregularities of the fringe pattern are a function of the irregularities of the test surface. If the test surface were perfectly flat, the fringes would be straight and parallel. Any curvature of the test surface introduces a corresponding curvature in the wave front of beam 2, and this wave front, when compared with the plane wave front of beam 1, introduces curvature into the otherwise straight fringes. By adjusting the tilt of the test surface (i.e., setting $\beta=\theta$ and introducing a slight tilt across the width of the test area), it is possible to adjust the fringes so that they run parallel to the long dimension of the test area (as seen by the observer at E). In this case, the curvature of the fringes is a direct and precise measure of the curvature of the test area (in its long dimension). The fringe pattern is a contour map of the area of the specimen surface that is being tested.

3. Sensitivity

The sensitivity of the instrument depends upon the value of β. Since the light is reflected twice from the specimen surface, the sensitivity is double that obtained with the Linnik interferometer for the same angle of incidence. When the instrument is adjusted as described in the preceding section, one fringe departure from straightness corresponds to a departure from flatness of $\lambda/(4 \sin \beta)$, where λ is the wavelength of light.

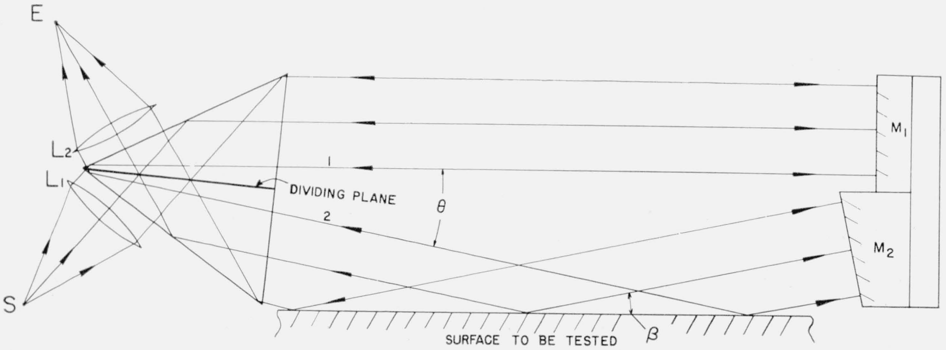

FIGURE 1. *Optical arrangement of the surface plate interferometer.*

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[1] Present address: University College, London, England.

[2] V. P. Linnik, Compt. rend. acad. sci. U.R.S.S. **35,** 16 (1942).

[3] J. B. Saunders, Construction of a Kösters double-image prism, J. Research NBS, **58,** 21 (1957) RP2729.

[4] The Kösters double image prism is made from two 30°–60°–90° prisms, one of which is partially silvered on the face opposite the 60° angle. The two prisms are then cemented together to form the equilateral prism shown in figure 1. The partially silvered surface becomes a semireflecting plane.

In a finished instrument, the angles θ and β could be made adjustable so that any length surface could be made to fill the aperture of the system. This would give maximum sensitivity for any size surface measured. However, since the value of β must be known for evaluating the fringe pattern, it may be more practical to use fixed values for θ and β (with M_1 and M_2 bound into a rigid unit) and bind the mirror unit to the prism housing. This would eliminate the necessity of making frequent measurements of β and also add stability to the instrument. The resulting instrument would have a fixed adjustment and could be used by an unskilled operator.

The maximum length of surface that may be covered with one setting is $A \csc \beta$, where A is the aperture of the prism. Thus by decreasing β, any length surface could be covered with a prism of a given aperture, but of course the sensitivity of the instrument would also decrease.

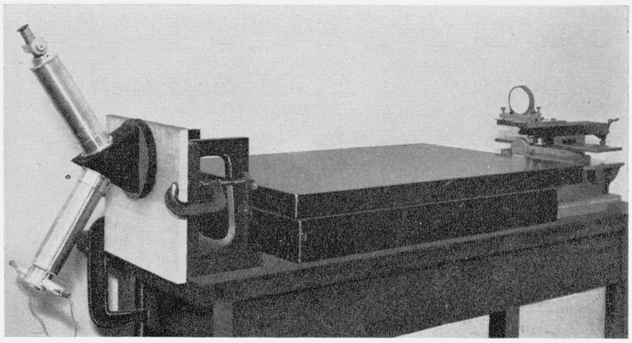

FIGURE 2. *Pilot model of surface plate interferometer for testing feasibility of the optical principals with a typical granite surface plate.*

The reflectivity of the end mirrors is designed to give approximately equal intensity for the two lightbeams at the receiving point E.

4. Experimental Model

Figure 2 is a photograph of the pilot model that was used to test the interferometer. The surface plate used in this assembly was 91 cm long. The wedge angle between the wave fronts was controlled by adjusting the end mirrors, which produced the same effect as tilting the surface plate. The Kösters double image prism and lens assembly shown in figure 2 were taken from another instrument that was designed for use with a clear circular aperture of

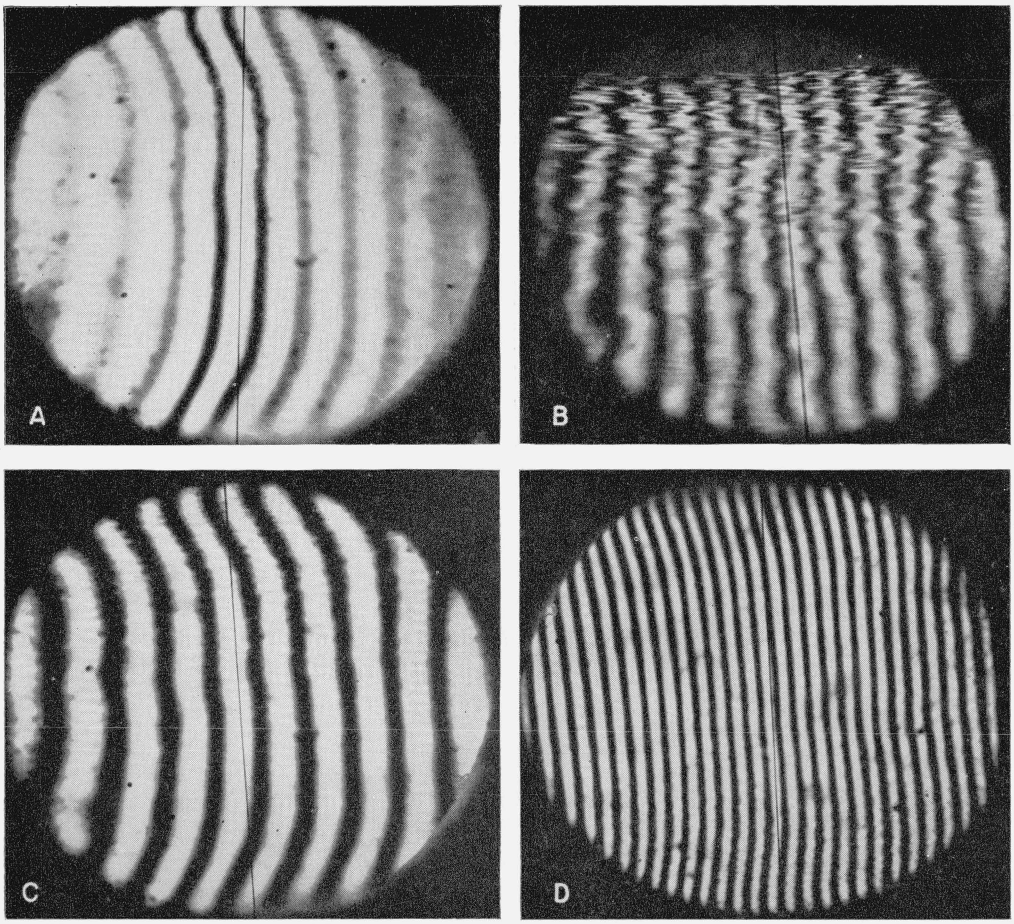

FIGURE 3. *Fringe patterns.*

A, White light from granite surface plate; B, monochromatic light from a badly scratched cast iron surface; C and D, monochromatic light from a granite surface. Angle of incident on surface plate is approximately 2½°.

51-mm diam (2 in.).[5] Since the prism had an aperture 51-mm square, better coverage of the specimen surface could have been obtained by increasing the circular aperture to $51\sqrt{2}$ mm. This would have left the square aperture of the prism unobstructed, so that the area of the specimen being tested would have been a rectangle 51 mm by 91 cm, and the unfavorable narrowing of the field at the ends of the specimen due to the circular aperture would have been eliminated.

5. Results

The interference fringes shown in figure 3 were taken with the instrument described above and shown in figure 2. Photograph A was made with white light and the others with monochromatic ($\lambda=5876$ A) light. The difference between photographs C and D was obtained by changing the angle between the two interfering wavefronts, thus changing the width of the fringes. Photographs A, C, and D of figure 3 were made with the plate of black granite, shown in figure 2, whereas photograph B was made with an old cast iron plate (dated 1918) that was badly scratched and marred. In this model the angle β was $2\frac{1}{2}°$ and thus a departure from straightness of one fringe corresponds to a deviation from flatness of $5.75\ \lambda$ (approximately 0.00013 in.).

The optical performance of this instrument was found to be highly satisfactory. Some mechanical development is necessary in order to produce a more practical instrument. Accordingly, a few suggestions given here may be of help to the designer. The prism should be designed to use its entire rectangular aperture. The apertures of the lenses should be sufficiently large to prevent constriction of this aperture. The prism and end mirrors should be rigidly bound together if vibrations of the fringes are to be avoided. White light may be used but the resulting difficulty of finding and adjusting the fringes exceeds the inconveniences associated with monochromatic sources.

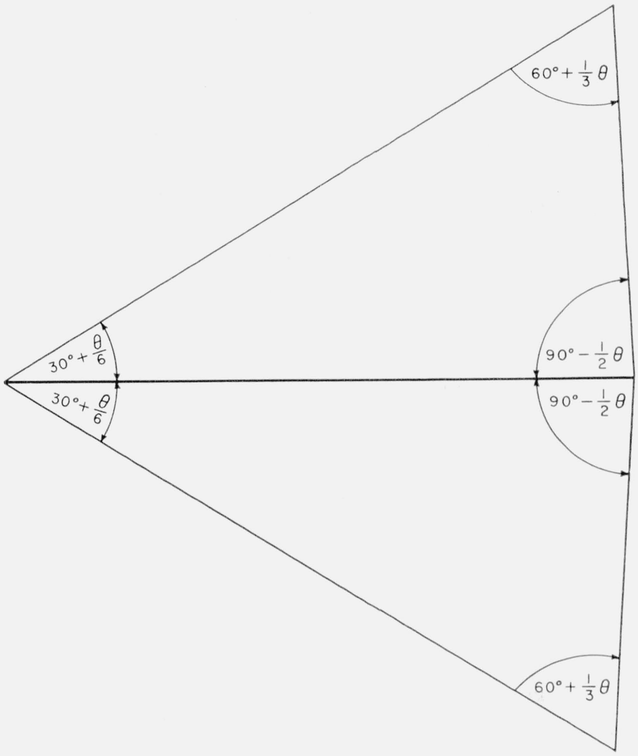

FIGURE 4. *Modified Kösters double-image prism for use with monochromatic light.*

A cover that encloses the light beams, between the prism and end mirrors, greatly enhances the stability of the fringes, and should be used unless the surrounding air is in a steady state. If white light is to be used, differential refraction may be reduced to a minimum by using the form of Kösters prism shown in figure 4. The procedure for making such a prism differs from that described in footnote 4 in that all surfaces are finished before cutting the prism into two parts.

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[5] This prism assembly was designed for use with $\theta=0°$. Using it at $\theta=2\frac{1}{2}°$, the circular aperture became an oval aperture with a vertical diameter of 45 mm.